GENERAL PHYSICS I: PHYS 10

Schedule - Fall 2007
(lecture schedule is approximate)

8	M	22	19	Chapter 7	Impulse and momentum	No lab or tutorial
	Tue	**23**	**MID-TERM TEST, Ch 1-5, Tuesday, October 23, 7-9 pm**			
	W	24	20	Chapter 7	Impulse and momentum	
	F	26	21	Chapter 8, sections 1-3 only	Rotational kinematics	
9	M	29	22			Experiment 3: Forces in Equilibrium
	W	31	23	Chapter 9 sections 1 - 3, 6	Rotational dynamics	
	F	**Nov 2**	24			
10	M	5	25	Chapter 10 exclude 10.7 and 10.8	Simple harmonic motion, sections 10.5 and 10.6, for self study only	Tutorial and Test 3 (chapters 7, 8)
	W	7	26			
	F	9	27	Chapter 11 exclude 11.11	Fluids	

Mastering Physics Assignment 3

Assignment 3 is available on the Mastering Physics website

It is due Friday, October 26 at 11 pm

It covers material from chapters 4 and 5 as preparation for the term test on Tuesday

There are 8 questions for practice and 6 for credit

Clickers!

Rate the PHYS 1020 midterm on a scale of A to E with

A = easy
E = difficult

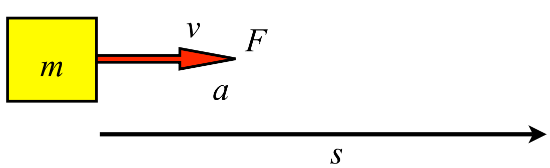
Power

Power is the rate of doing work, or the rate at which energy is generated or delivered.

Unit: 1 watt (W) = 1 J/s

$$\text{Power, } P = \frac{W}{t} = \frac{Fs}{t} = F \times \frac{s}{t} = Fv \qquad \text{(speed = distance/time)}$$

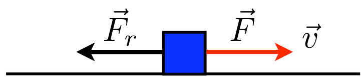
P = Fv



Kilowatt-hour (kWh): the energy generated or work done when 1 kW of power is supplied for 1 hour.
1 kWh = (1000 J/s)×(3600 s) = 3,600,000 J = 3.6 MJ

6.60: A motorcycle (mass of cycle + rider = 250 kg) is travelling at a steady speed of 20 m/s. The force of air resistance on cycle + rider is 200 N. Find the power necessary to maintain this speed if a) the road is level and b) slopes upward at 37^0.

a)

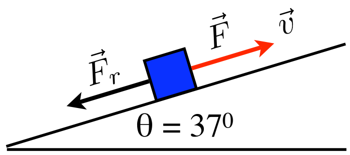


Work-energy theorem: $W_{nc} = \Delta KE + \Delta PE$, and $\Delta KE = \Delta PE = 0$

The force supplied by the engine $F = F_r = 200$ N

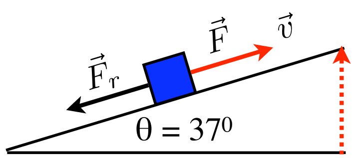
Power needed, $P = Fv = 200 \times 20 = 4000$ W (5.4 hp)

b)



The motorcycle gains potential energy, so an extra amount of energy must be supplied by the engine.

b)



Work-energy theorem: $W_{nc} = \Delta KE + \Delta PE$, and $\Delta KE = 0$

In 1 s, cycle goes up an amount $h = v \sin\theta$ (travels distance v in 1 s)

So, extra work done by engine in 1 s is given by $\Delta PE = mgv \sin\theta$

So, $P = 4000 + mgv \sin\theta$

$= 4000 + 250 \times g \times 20 \sin 37^0$

$= 33{,}500$ W (45 hp)

Other Forms of Energy

There are many forms of energy:

- Electrical
- Elastic (eg energy stored in a spring)
- Chemical
- Thermal
- Nuclear

Energy is conserved overall:

Energy may be converted from one form to another, but the total amount of energy is conserved.

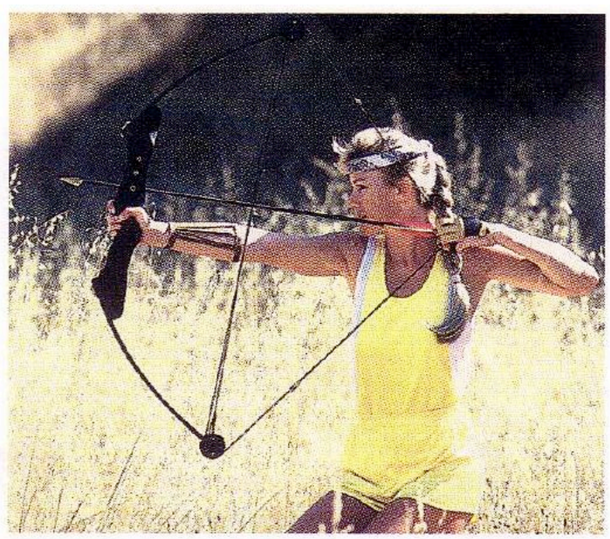
Work done by a variable force

Example: compound bow

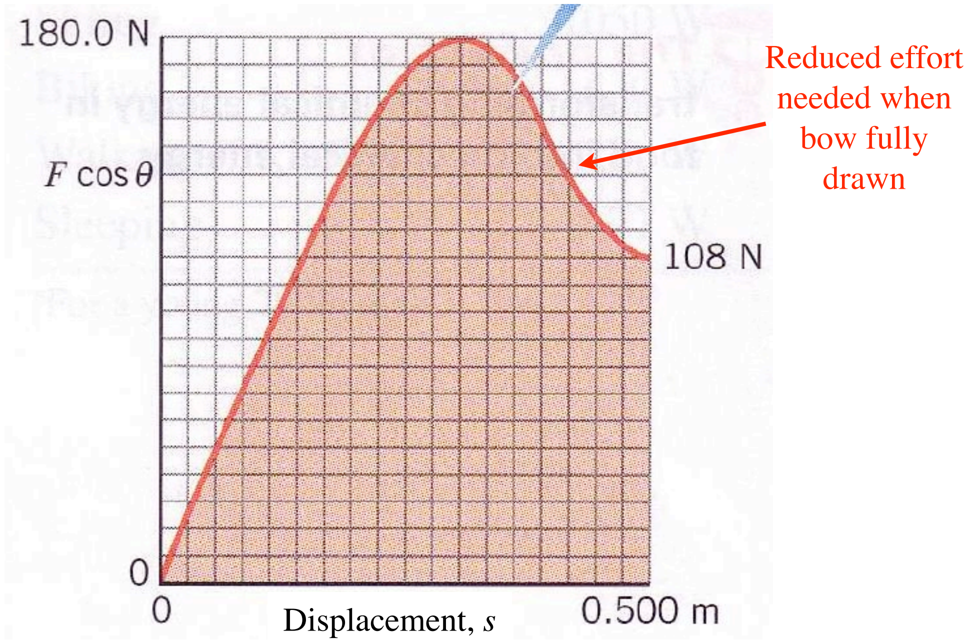
– a number of pulleys and strings

- maximize the energy stored in the bow for finite effort

- reduced force with bow fully drawn.

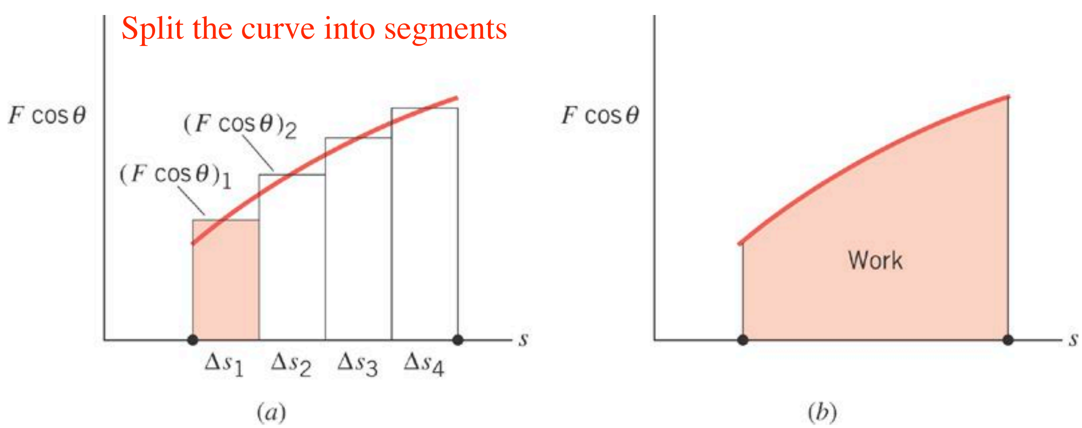


Force to draw the bow



How much work is needed to draw the bow?

Work done is force × distance...



$$W \simeq (F\cos\theta)_1\Delta s_1 + (F\cos\theta)_2\Delta s_2 + \ldots$$

= sum of force × distance

Becomes exactly the area under the curve when the slices become vanishingly narrow → integral calculus

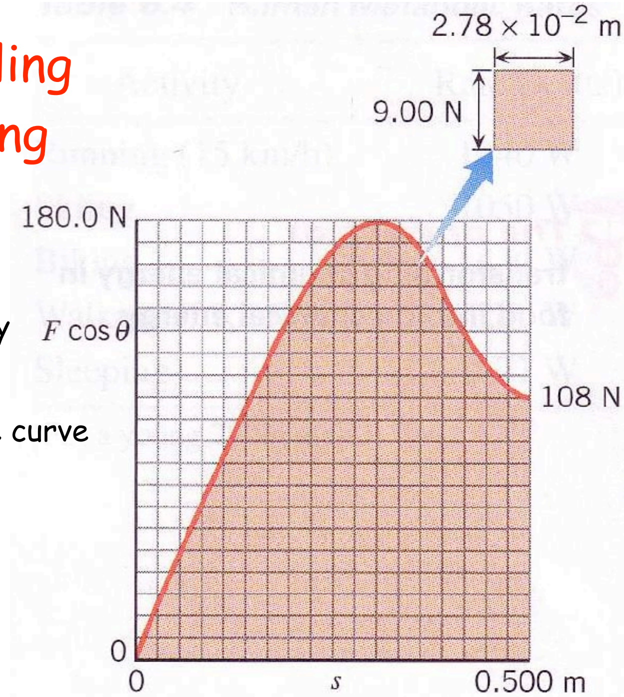
Work done in pulling back the bowstring

Work done in drawing the bow = area under the curve

Count the squares, multiply by area of each.

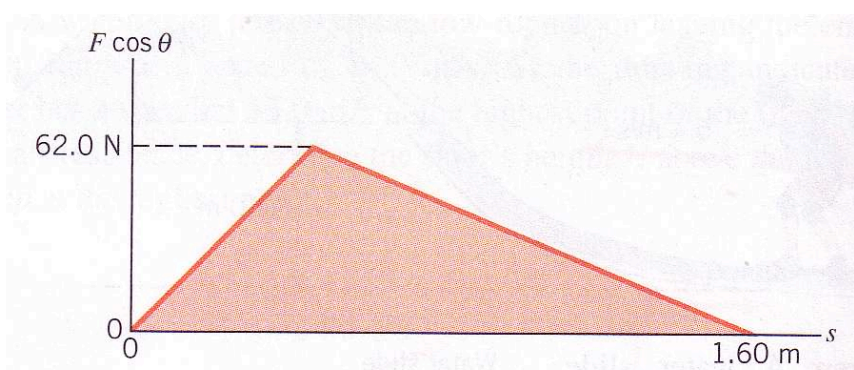
Number of squares under the curve ≈ 242.
Area of each square is:

(9 N) × (0.0278 m)
= 0.25 N.m = 0.25 J.



So, work done is W = 242 × 0.25 = 60.5 J

6.66/64



Work done = area under triangular curve

$$= \frac{1}{2} \times (\text{base}) \times (\text{height})$$

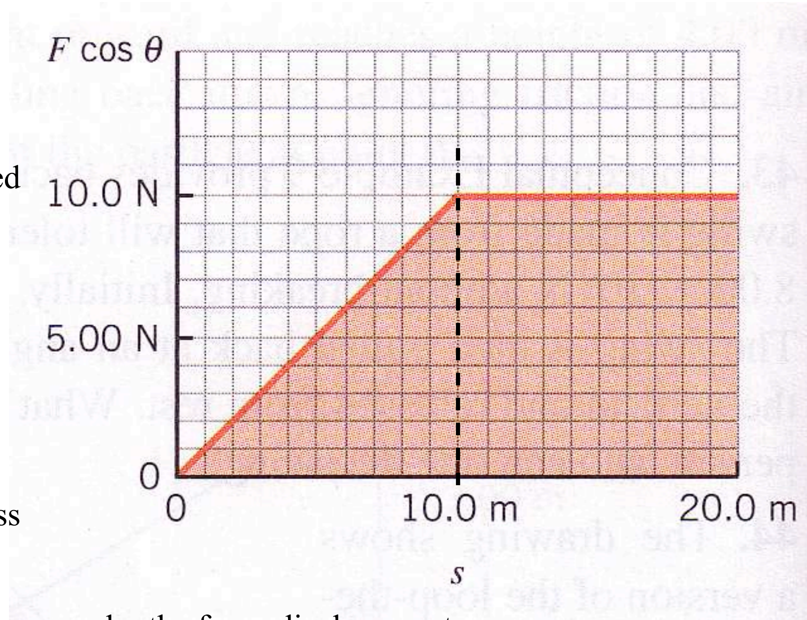
$$W = 0.5 \times (1.6 \text{ m}) \times (62 \text{ N}) = 49.6 \text{ J}$$

6.67

A force is applied to a 6 kg mass initially at rest.

a) How much work is done by the force?

b) What is the speed of the mass at s = 20 m?



a) Work done = area under the force-displacement curve

$$W = \frac{1}{2} \times (10 \text{ m}) \times (10 \text{ N}) + (20 - 10 \text{ m})(10 \text{ N}) \; = 150 \text{ J}$$

b) What is the speed of the mass at s = 20 m?

$$\underline{W_{nc}} = \Delta KE + \Delta PE = \underline{mv^2/2 + 0} \quad = 150 \text{ J}$$

$$v = \sqrt{2W_{nc}/m} \; = \sqrt{2 \times 150/6} = 7.07 \text{ m/s}$$

Summary

In absence of non-conservative forces:

Conservation of mechanical energy: E = KE + PE = constant

When non-conservative forces are present (friction, applied forces...):

Work-energy theorem: $W_{nc} = \Delta KE + \Delta PE$

Power = rate of doing work (1 W = 1J/s)

P = Fv

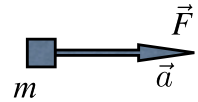
Work done by a variable force = area under the force versus displacement curve

Chapter 7: Impulse and Momentum
Newton's Second Law in Another Guise

- Impulse-Momentum Theorem
- Principle of Conservation of Linear Momentum
- Collisions in One Dimension
- Collisions in Two Dimensions
- Centre of Mass

Impulse and Momentum

Newton's second law: $\vec{F} = m\vec{a}$



Or $\vec{F} = m\dfrac{\Delta\vec{v}}{\Delta t}$

So $\vec{F}\Delta t = m\Delta\vec{v}$

$\vec{F}\Delta t$ is the *impulse* of the force $\vec{F}$

Define momentum $\vec{p} = m\vec{v}$

Then $\vec{F}\Delta t = m\Delta\vec{v} = \Delta p$ (Impulse-momentum theorem)

That is, impulse = change in momentum

$$\vec{F}\Delta t = m\Delta\vec{v} = \Delta p$$

If $\vec{F} = 0$, then $\Delta\vec{p} = 0$

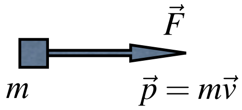
That is, momentum is conserved when the net force acting on an object is zero.

This applies also to an isolated system of two of more objects (no external forces) that may be in contact - the total momentum is conserved.

Compare Newton's first law: velocity is constant when the net force is zero.

Alternative formulation of Newton's second law

$$\boxed{\vec{F}\Delta t = m\Delta\vec{v} = \Delta p}$$

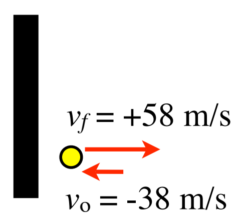


OR: $$\boxed{\vec{F} = \frac{\Delta\vec{p}}{\Delta t}}$$

The net force acting on an object is equal to the rate of change of momentum of the object.

A 0.14 kg baseball has an initial velocity v_0 = -38 m/s as it approaches a bat.

The bat applies an average force F that is much larger than the weight of the ball.



After being hit by the bat, the ball travels at speed v_f = +58 m/s.

a) The impulse applied to the ball is $mv_f - mv_0 = m(v_f - v_o)$

Impulse = (0.14 kg) × (58 - (-38)) = 13.44 N.s (or kg.m/s)

b) The bat is in contact with the ball for 1.6 ms.

The average force of the bat on the ball is

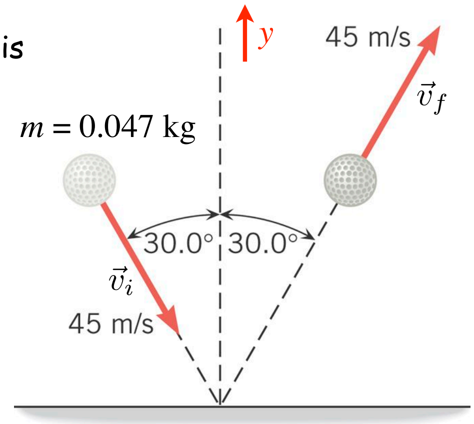
F = Impulse/time = (13.44 N.s)/(0.0016 s) = 8,400 N

7.13/9: A golf ball strikes a hard, smooth floor at an angle of 30^0, and rebounds at the same angle. What is the impulse applied to the golf ball by the floor?

NB: velocity in sideways direction is unchanged

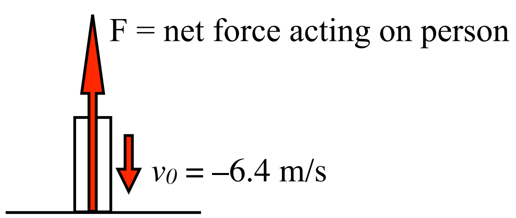
$v_i = -45 \cos 30^0$ ← In y-direction
$v_f = +45 \cos 30^0$
$m = 0.047$ kg

Impulse $= p_f - p_i$
$= m(v_f - v_i)$
$= 0.047(45 + 45)\cos 30^0$
$= 3.7$ N.s



7.50/8: Absorbing the shock when jumping straight down.

a) A 75 kg man jumps down and makes a stiff-legged impact with the ground at 6.4 m/s (eg, a jump from 2.1 m) lasting 2 ms. Find the average force acting on him in this time.



Change in momentum = impulse = force × time

$$F\Delta t = \Delta p = 0 - mv_0$$

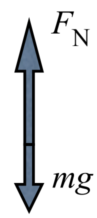
$$\text{So } F = -mv_0/\Delta t = (75 \text{ kg} \times 6.4 \text{ m/s})/(0.002 \text{ s}) = 240{,}000 \text{ N}$$
$$= 327mg \text{ !!}$$

b) After extensive reconstructive surgery, he tries again, this time bending his knees on impact to stretch out the deceleration time to 0.1 s.

The average force is now: $F = -mv_0/\Delta t$

$$F = 75 \times 6.4/0.1 = 4,800 \text{ N} = 6.5mg$$

c) The net force acting on the person is:



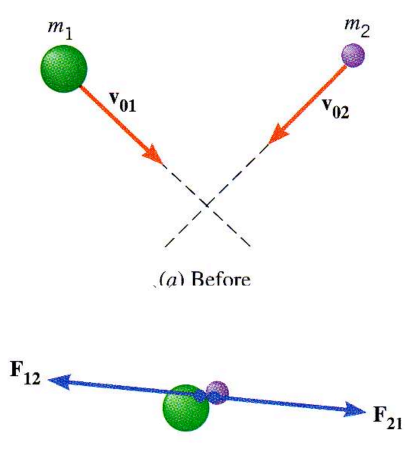
$$F = F_N - mg$$

So the force of the ground on the person is:

$$F_N = F + mg = F + 75g$$

$= 5535$ N = momentary reading on bathroom scales, equivalent to weight of a 565 kg mass.

Conservation of Momentum



(a) Before

(b) During

Two isolated masses collide. The initial total momentum is:

$$\vec{p} = \vec{p}_1 + \vec{p}_2$$

with $\vec{p}_1 = m_1\vec{v}_{01}$

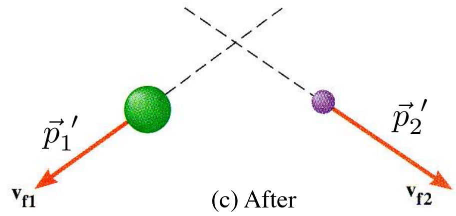
$\vec{p}_2 = m_2\vec{v}_{02}$

While the masses are in contact, they exert equal and opposite forces on each other (Newton's third law).

$$\vec{F}_{12} = -\vec{F}_{21}$$

So the impulse acting on m_1 is equal in magnitude and opposite in direction to the impulse acting on m_2

So the *impulse* acting on m_1 is equal in magnitude and opposite in direction to the *impulse* acting on m_2



Therefore, $\Delta\vec{p}_1 = -\Delta\vec{p}_2$ (change in momentum = impulse)

After the collision: $\vec{p}_1' = \vec{p}_1 + \Delta\vec{p}_1$

$$\vec{p}_2' = \vec{p}_2 + \Delta\vec{p}_2 = \vec{p}_2 - \Delta\vec{p}_1$$

So, the total momentum after the collision is:

$$\vec{p}' = \vec{p}_1' + \vec{p}_2' = (\vec{p}_1 + \Delta\vec{p}_1) + (\vec{p}_2 - \Delta\vec{p}_1)$$
$$= \vec{p}_1 + \vec{p}_2$$
$$= \vec{p}$$

That is, $\vec{p}' = \vec{p}$ and the total momentum is conserved.